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A DISTRIBUTED DATA ACQUISITION AND MONITORING SYSTEM FOR THE BEAM INSTRUMENTATION OF LEP

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ABSTRACT

The beam instrumentation for LEP is comprised of a number of detectors such as current transformers, split foil monitors, interaction and background monitors and electrostatic pick-ups. These intruments are interfaced using about 100 VME crates spread over 25 stations located around the 27 km of LEP. The crates are connected to the control system using MIL/STD-1553, an Olivetti M380 running XENIX and an IBM Token-Ring. Each crate is equipped with a Themis TSVME106 CPU board which runs the MOTOROLA RMS68K operating system kernel. A set of services (alarms, communications, i/o system, libraries, log book, timing, etc) has been implemented and constitutes a comfortable environment for the application programs. Most of the programming is done in PASCAL, using a cross compiler developed and maintained at CERN. A set of utilities running in the Olivetti M380 and in the crates provides system monitoring, system and application reload, surveillance of the behaviour of the system and of the application tasks.

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INTRODUCTION

Accelerator control by means of computers at CERN was introduced towards the end of the 1960s [1] but the real quantum jump came in the middle 1970s, when the SPS was completely controlled by a large number of networked minicomputers[2]. Control and monitoring equipment was interfaced to the computer system via CAMAC or an inhouse product, the MPX. These interfaces merely adapted the signals going to and coming from the detectors, magnets, collimators, etc [3,4]. The processing power needed to operate the equipment, calculate, optimize, display and, dispatch the data to the controls center was provided by the local process minicomputer which also had to cope with the real-time constraints imposed by the operation. However, signs soon started to appear indicating that a change in the architecture was needed and some of the most demanding tasks were extracted and entrusted to dedicated processors housed in CAMAC crates. Where this was not possible, a solution involving the duplication of the computers to share the load was adopted. Enriched by this experience, following the trends of industry and taking advantage of modern technology, the builders of the LEP control system and its users have distributed the load to the periphery. Dedicated processors have blossomed at great distances from the control center. Their complexity depends on the equipment controlled and they range from simple single-task systems to those resembling full blown computers with associated hardware and services. In the LEP control system these peripheral processors interfacing to equipment are called Equipment Control Assemblies. The beam instrumentation group chose to use VME crates to interface its equipment. The object of this paper is to describe the individual structure of these ECAs and the architecture of the system they form, together with the control, the data and the timing paths for beam instrumentation.

THE BEAM INSTRUMENTATION EQUIPMENT CONTROL ASSEMBLY

Despite the great variety of the beam instruments, all the ECAs used to interface them share a same basic hardware and software. The hardware is housed in a 20-slot VME crate. The following modules form the kernel of the ECA hardware :

- a 68010-based CPU module containing a memory management unit, 1 Mbyte of dynamic random access memory, 500 kbytes of battery-backed static random access memory, a clock calendar and two serial ports [5],
- a MIL/STD-1553 remote terminal interface [6],
- a General Machine Timing receiver module [7],
- a Beam Synchronous Timing receiver module.

Particular configurations of general-purpose input/output modules, as well as special purpose modules, differentiate the ECAs dealing with different applications. The choice of the CPU module was dictated by :

- the power and type of processing required,
- the size of the application software, the kernel and its services,

-the desire to protect the system from accidental memory corruptions,

- the need for an autonomous reboot capability not needing a network download with the possibility of remote downloading of new versions of the software,

- the availability of a hardware watchdog.

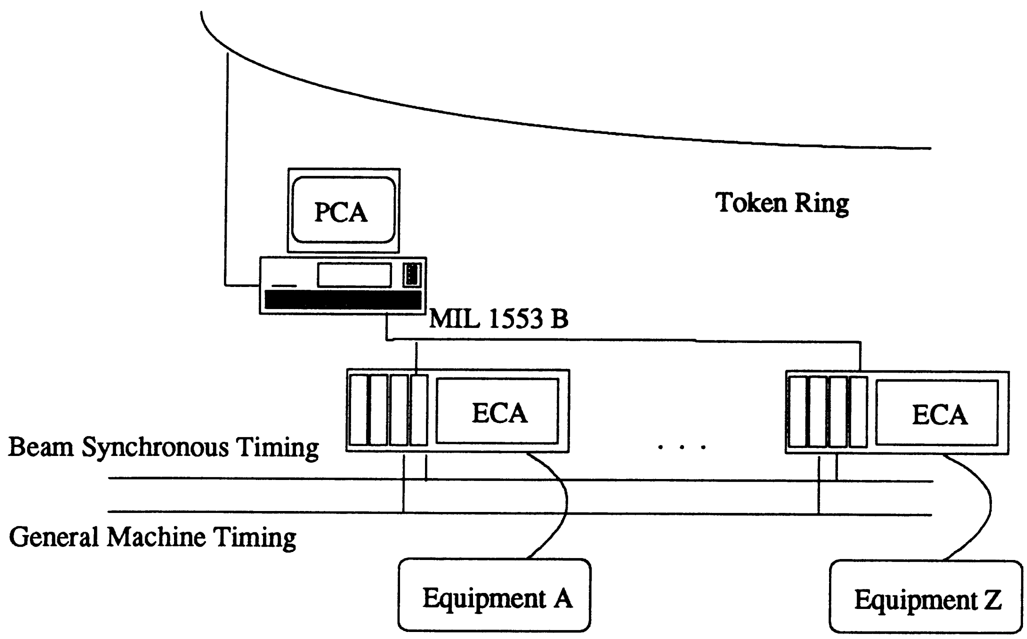

Figure 2

A computer, called Process Control Assembly in the LEP jargon [8], acts as a middle man between the ECAs and the LEP operator: it interfaces the MIL/STD-1553 to the LEP token ring, provides a network interface for equipment access functions and is a platform for local surveillance programs. This computer is at present an IBM-PC compatible and runs SCO-XENIX [Fig.1]

The software dealing with the beam instrumentation is distributed in three major areas: the ECA itself (embedded software [9]), the PCA (support and management) and a special surveilllance computer.

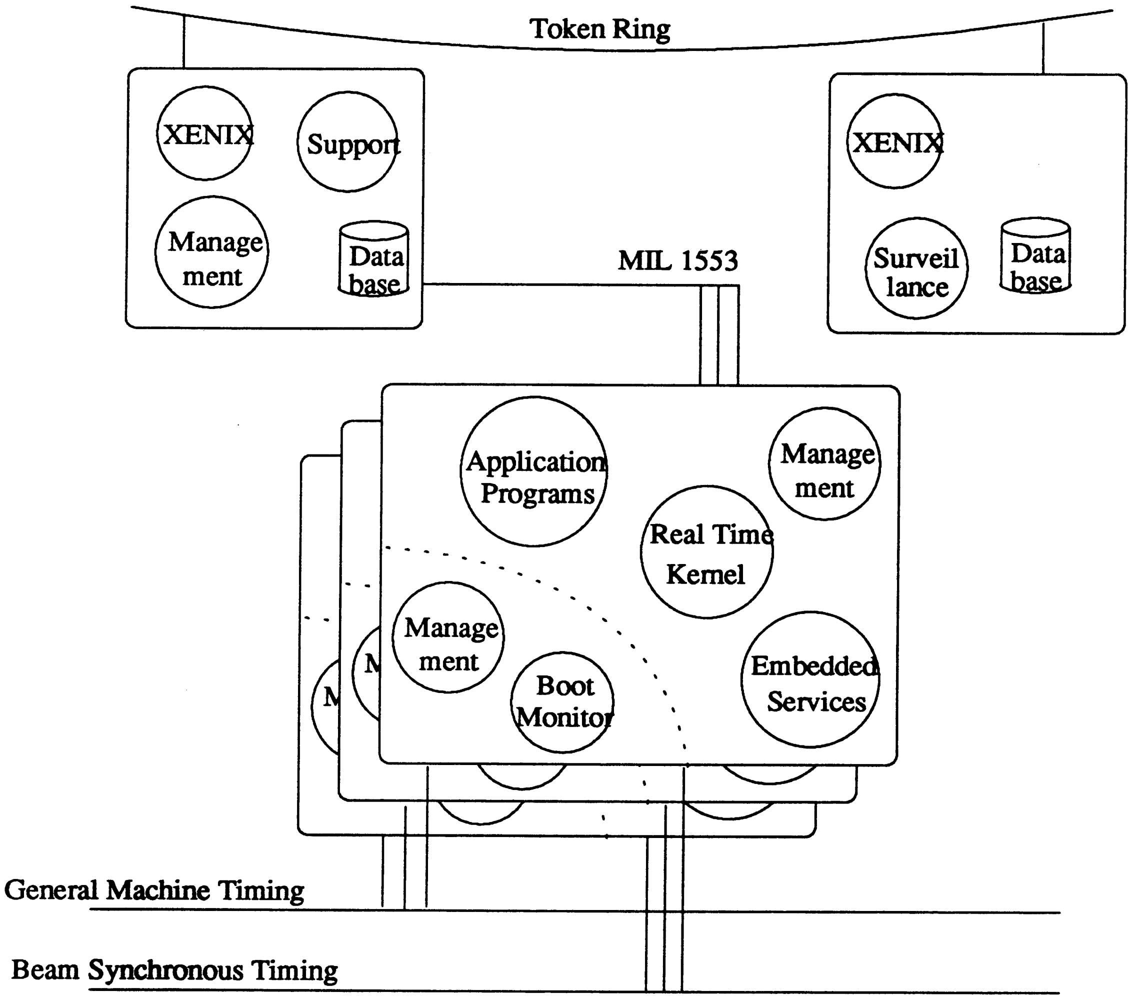

Figure 2

The embedded software consists of the collection of independent and cooperating tasks handling the equipment to which the ECA interfaces, a set of services and library, and the real-time kernel [Fig.2].

This software is down-line loaded and kept in a battery protected memory. At system startup, a boot monitor, situated in an onboard EPROM, takes control of the ECA and waits for either terminal input, or the establishment of a communication session on the MIL/STD-1553; if neither of those take place, it copies the application software, the system and its services from the battery protected memory on to its dynamic memory and starts the operating system kernel. The whole procedure lasts about 10 seconds.

The communication with the boot monitor via the MIL/STD-1553 allows system management functions such as the down-line loading of new versions, analysis of crash dump areas and the inspection of device registers, from any console of the LEP control system.

Every system, regardless of the device to which it is interfaced, contains a set of special tasks which allow time and date synchronization with the General Machine Timing, application task startup, system status analysis (list of tasks), system control possibilities (start, kill, create tasks), application service status analysis (list of open services and their characteristics) and memory dump facilities.

The PCA, when the ECA starts up, receives a service request, which triggers the execution of a program keeping track of this type of events: it monitors the frequency and logs the date, time and ECA identification. In case of a high reboot rate , particular memory areas are dumped on a file and the software in the ECA is completely reloaded.

Finally, when all the tasks have started, the exception monitor (a privileged task in the system) informs the PCA, which launches the application initialization program. This program, which is tailored to each device, carries out the particular initialization sequence needed for each instrument to start correctly. Typically, calibration data and device characteristics are loaded and normal operation of the device is authorized.

During normal operation, a task in the ECA continuously monitors the Beam Synchronous Timing and the General Machine Timing. If a loss of synchronization of the former is detected, the program in the PCA is invoked, which will log the error and try to re-establish the correct operation state. For the latter, in case of loss of signal, the date and time acquisition is switched to an onboard clock calendar module; when the GMT is back on the air, time acquisition is switched back to it.

Each PCA which controls beam instrumentation ECAs holds a database containing the list of them. In order to prevent access clashes, the support programs consult this database before taking any action at startup, error recovery etc. A set of programs allows this distributed database to be consulted and updated remotely .

A set of tools, the development of which is continuing, allows the monitoring of the ECAs in the collider tunnel; the following information can be acquired readily: the date of the last restart, the rate of the restarts, the initialization logbooks, the version of the embedded software, the date of last reload, the timing error rate, the date of the last timing error, system status, application services status and some diagnostics. The following actions can be taken: restart an ECA, reload its system, reload its application software, install a new application software version, control the timing hardware, read and set the time and dump the memory.

Every 10 minutes, each system is interrogated for a status report; if it does not respond correctly, depending on the gravity, it is either reset or completely reloaded. When an ECA exhibits a strange behaviour, the surveillance is extended to its application tasks. Every system restart or reload is logged.

THE CONTROL, DATA AND TIMING PATHS

As for any device connected to the LEP Control System, the ECAs for beam instrumentation receive commands via the MIL/STD-1553 [10,11]. Typically, initialization commands and the associated data travel via this path. The time needed for a command initiated in the PCA to reach the ECA is of the order of 100 ms. Where synchronization of device operation is not needed, this path is perfectly suitable, but when commands must be received synchronously by several instruments situated in different parts of the collider, it cannot be used. In order to command acquisition of the beam orbit measurement system and be able to correlate data acquired by other instruments situated in different points of the collider, the beam instrumentation group has developped an alternate control path called the BST [12,13]. Control information is carried together with a timing pulse (every 88.9 us) and is guaranteed to arrive at the same time (within 50 ns) at all the stations. Up to six different instruments can be driven at the same time. Data is stamped with the date delivered by the GMT, which is precise to the second, plus the LEP turn number given by a 15 bit counter covering approximately 3 seconds.

Data acquired by the instruments is transferred out of the ECA either by a transaction initiated by the PCA or by a program residing in the ECA and triggered by a BST command. In both cases the data is transmitted over the MIL/STD-1553. A narrower bandwith, but much faster, data path allows devices connected to the BST to transmit data to the control center in the form of a signal. This path is used when fast intervention is needed, for example to stop beam losses. The reaction time is of the order of 10 LEP turns (< 1 ms).

CONCLUSION

From the first few months of experience it can be said that the aim of making the system fault tolerant has been attained. Despite the fact that there is about one ECA crash per day, seldom does the operations team becomes aware of it. The system is capable of recovering easily from incidents such as communications system failures, power cuts or timing failures. The cost of this are computer time consuming surveillance programs which have sometimes caused problems in the initial phases of their development.

The ECA monitoring facilities constitute a comfortable tool for specialist and have in most cases helped to find and cure the problem encountered. The set of management programs in the PCAs and on the other control system computers allow easy and secure changes to the configuration, the installation of new versions of the software and the reversal to an old version.

The different communication paths have proved to have sufficient bandwidth (tens of kbytes) to support the flow of data generated by the beam instruments and to provide the data to the operator in the controls center after a reasonable delay (tens of seconds) which can be shortened.

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